Ballast lifetime calculations

Ballast lifetime calculations are one of the most difficult items to be calculated because it is determined by the lifetime of all the components used and the amount of stress (voltage, current and temperature) on each of these components.

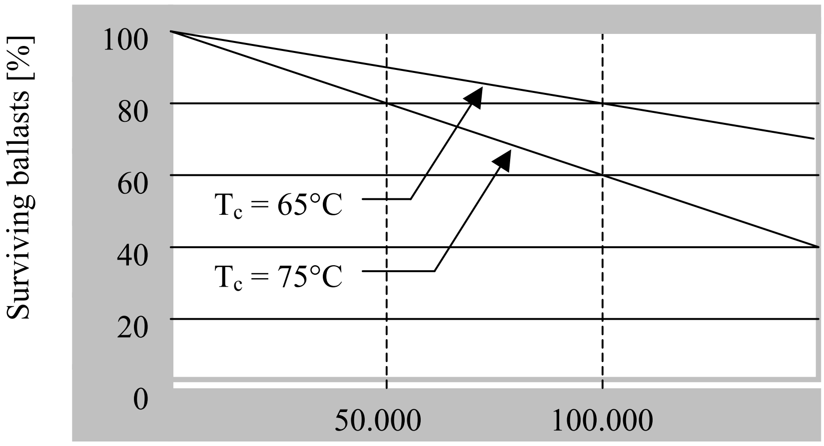
The lifetime of an individual component is mainly dependent upon the quality of the materials used and the manufacturing process of this component. Usually, each component is checked not only for proper functioning immediately after manufacturing, but also in use. Typical for electronic components is that if they have defects, these will show up in the early hours of operation. After this so-called burn-in period failures will only very seldom occur. Philips electronic ballasts undergo a burn-in period for a specified period before leaving the factory. The purpose of this is to reduce the chances of early failures in an installation as much as possible. In order to control the failure rate of a complete ballast, the method of calculating the Mean Time Between Failures (MTBF) is adopted. This takes into account the MTBF of all the individual components. The Failure Rate (FR) is 1 divided by the MTBF. Since the maximum temperature within a luminaire is very important for the lifetime of a ballast, the calculations are normally based on a temperature of 65 °C at a defined spot on the ballast enclosure (t_c point). The quality of the design and of the components must result in a certain specified calculated failure rate. For most electronic ballasts this is set to 1 per cent at 5.000 hours. According to the equation:

$$R_t = e^{-\lambda t} \qquad \text{or} \qquad \ln R_t = -\lambda t$$

where R_t is the remaining number of ballasts after the time t and λ is the failure rate of 1% per 5.000 hours = 0.20 .10^{-5}, it is found that 36.7 per cent of the ballasts are still operational after 500.000 hours or 50 per cent after 346.000 hours. The 10 per cent failure rate is reached after 52.680 hours. The temperature dependence of the failure rate can also be calculated. For most electronic ballasts this gives the following figures:

Test-point temperature (°C)	Failure rate (% per 1.000 hours)			
	HF/B-P	HF-R	e-Kyoto	e-Matchbox
55	0.05	0.15	0.20	0.10
65	0.10	0.20	0.28	0.20
75	0.20	0.30	0.43	0.40

These calculated figures are verified by lifetime tests for the various ballasts (see **Picture 1**). One of the reasons for the increase in the failure rate at higher temperatures is the temperature dependency of capacitors employed, especially the electrolytic buffer capacitor and the soldered contacts of all the components.



Picture 1 (failure rate of 0.2% per 1.000 hours)

In order to verify the outcome of calculations, lifetime tests are continuously carried out on batches of ballasts. It is found that during a long period after the burn-in period the lifetime of the ballasts is in accordance with the calculated failure rate. But after this long period, the failure rate then increases very rapidly, ultimately resulting in the end of the lifetime of the batch of ballasts (see **Picture 2**). There are two major reasons for this phenomenon: drying up of the liquid of the electrolytic capacitors, and degradation of the soldered contacts. The soldered contacts are specified to have a lifetime of 2.500 to 3.000 switches in the temperature-change test of -20 °C to +100 °C. This wide temperature range of 120 degrees will not be found in practice, temperatures between + 20 °C and + 60 °C (a range of 40 °C) are more likely.

The actual switching lifetime can be calculated from the following equation:

$$N_{switch} = 2.500 \text{ x } (120 / \text{practical temperature range})^2.$$

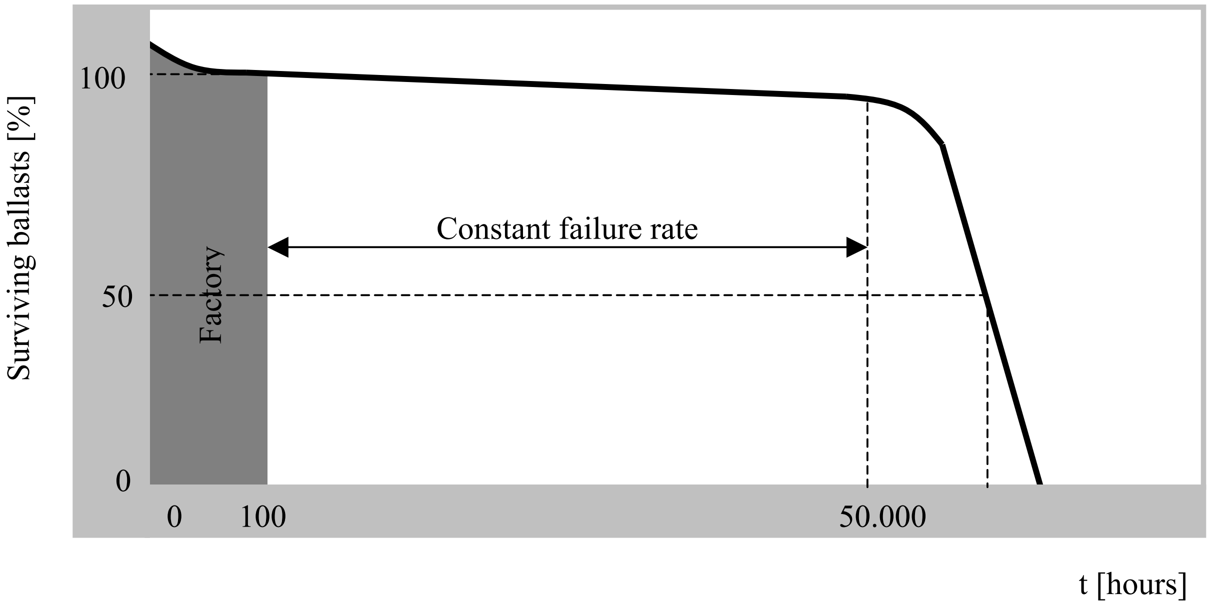
So in this example:

$$N = 2.500 \text{ x } (120/40)^2 = 2.500 \text{ x } 9 = 22.500 \text{ times.}$$

Supposing the average burning time of the fluorescent lamps is 2 hours, this would result in a lifetime of the complete ballast of 2 x 22.500 = 45.000 hours.

The time after which 10 per cent of the ballasts have failed is called the Constant Failure rate lifetime. For most ballasts in normal operation, this Constant Failure rate lifetime is approximately 50.000 hours at nominal conditions and at a fixed specified case temperature (65 °C). A temperature increase of 10 degrees halves this Constant Failure rate lifetime (thus, 75 °C gives 25.000 hours), while 10 degrees lower doubles this figure (55 °C gives 100.000 hours).

Taking into account all various tolerances and spreading in components the final lifetime expectations will result in a graph like you can see in the picture below (**Picture 2)**.



Picture 2 (failure rate of 0.2% per 1.000 hours)